Study of Rice Straw Biocomposite and a Comparative Study of Flexural Strength of Various Biocomposite Plywood Materials

Swadesh Kumar Singh, Jandhyala N Murthy, PAPN Varma, and D Sailaja

Abstract**—**Green building is a movement that has gained the global attention over the past few years. Green buildings are planned to be environmentally responsible, economically viable and healthy places to live and work. One of the main materials currently used in green buildings is biocomposite. In the present work detailed study for the rice straw biocomposite is performed and a comparison of flexural strength is made between different biocomposites. Some of the biocomposites used in the present research are sugarcane bagasse plywood, particulate plywood composite, pure teak wood and plywood manufactured by different layers of nu-wood.

Keywords**—**Green Building; Biocomposite; Rice Husk Biocomposite; Plywood.

I. Introduction

A BIOCOMPOSITE is a material formed by a matrix (resin) and a reinforcement of natural fibres (usually derived from plants or cellulose). (consider this as components is too vague). Biocomposites are made of two or more components mixed together to form complex substances with new dimensions of properties. In recent times there has been an increasing demand for developing composite substances using natural and synthetic components which may be used for building and construction purposes like partition boards, preframed roofing, plywoods and flooring materials with low cost and high durability. The raw materials used for this purpose if they are derived from natural renewable resources or environmental wastes or industrial wastes then such biocomposites would be cheaper and available even to a common man. Keeping such demand in view, present study is aimed to have review and experimentation on certain biocomposite materials using various natural biowaste resources mixed in various combinations reinforced in synthetic resins like urea formaldehyde, phenol formaldehyde, tannins etc. for various building purposes depending on their strength.

According to their manufacturing processes, wood-based boards are classified into wet process fibreboards (fibre distribution takes place in water) and dry process fibreboards (fibre distribution takes place in air). Wet process boards are classified according to their density into hardboards and medium boards [1]. Medium density fibreboard is a generic term for a panel primarily composed of lignocellulosic fibres combined with a synthetic resin or other suitable bonding system and bonded together under heat and pressure. The panels are compressed to a density of 500-800kg/m^3. Additives may be introduced during manufacturing to improve certain properties. Because fibreboard can be cut into a wide range of sizes and shapes, applications are many, including industrial packaging, displays, exhibits, toys and games, furniture and cabinets, wall paneling, molding and door parts. Few techniques usually applied to produce fibreboards are thermomechanical pulping and chemithermomechanical pulping. The fibre separation is achieved by using grinding or refining or a combination of them. Grinding involves the pressing of wood logs against a revolving pulp-stone, while in refining wood chips are disintegrated in a revolving disc refiner. As a result, wood fibres are fractured and the resulting pulp is consisting of fibres of various lengths, fibre fragments and shives [2].

Nowadays, there are several potential applications for medium density fibreboards in many fields and the rate of manufacturing is increasing across the world. The cabinet doors, shelves, laminated floors, furniture, panels for building construction are typical products of medium density fibreboards. The commonly used method, for producing medium density fibreboards and high density fibreboards, employs wood-based raw materials (softwood and hardwood). The majority of wood raw materials are mainly utilized for sawn lumber products and in the pulp and paper industry. Therefore, demand for non-wood lignocellulosic fibre resources is also increasing, due to the lack of wood raw materials and for environmental and economic considerations. Currently the most commonly used non-wood materials are bamboo, hemp, jute, kenaf and bagasse as well as cereal straws (rice and wheat straw).

In biocomposite materials fibres are woven into mats and mats are dipped in synthetic resins to develop structural frames called fibreboards. The synthetic resins act like filler and give strength to the biocomposite material. In some biocomposite combinations where the lignin concentration is high, additional adhesive binders may not be required as lignin under heat and pressure flow act as thermosetting

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adhesive. In some other cases powdered husk, neem seed powder and adhesive substances are mixed in water and can be used for making structured frames. These methods vary depending on the combination of natural components used for making biocomposite materials. Due to the lower cost of rice straw (as it is agricultural residue and a non-wood material) it can be considered as another alternative source of lignocellulosic fibres. Few investigations were reported on rice straw-based fibreboard manufacturing. In most applications, the rice straw fibres are mixed with other lignocellulosic materials, or manufactured from rice straw pulp [3]-[4]. Rice straw was used as a raw material in the production of thin medium-and high-density fibreboards [4]. Rice straw possesses higher wax, ash and silica contents compared to other straws and wood Table-I gives the detailed composition of various elements in the rice straw, sugarcane bagasse and spruce wood [1, 5]. The fibrous residue of sugarcane after crushing and extraction of its juice, known as 'bagasse', is one of the largest agriculture residues in the world. An analysis of sugarcane bagasse indicates that its main constituents are cellulose, hemicellulose, lignin, ash and wax. Both sugar cane comrind and their mixture with hardwood are used with phenol formaldehyde resin and wax to manufacture composite board.

Wetting of untreated straw and applying water based adhesive to the chopped straw is considered as a technical challenging point due to the presence of the thin wax layer that covers the epidermal cells/outermost surface cells. This wax layer obstacles the penetration of the adhesive and proper gluing of the straw or acts as a barrier for the absorbance of water-based adhesives. Removing this wax layer is considered as a technical problem for the production of the rice straw based fibreboards and makes rice straw impractical. This has directed many researches and manufacturers to wheat straw as a raw material for producing fibreboards. The problem of pulverizing the wax layer and producing rice straw based medium density fibreboards has provided a motivation for the present work.

TABLE I
COMPOSITION IN VARIOUS BIOCOMPOSITES

Material	Wax	Hemicel lu-lose	Cellulos e	Lignin	Ash	Silica
Rice straw	3.72	35.5	39.63	13.92	12.51	9.68
Sugarc-ane bagasse	0.95	29	51	15	2.5	2.0
Spruce wood	1.47	23.4	54.09	30.15	0.24	-

Though, the chemical composition, heterogeneous structure and complex morphology structure of rice straw, its fibres have a potential application for manufacturing of fibre composites. This is because of their lignocellulosic characteristics [1]. Chemically, lignocellulosic rice straw fibres have relatively similar compositions as other natural fibres (fibres of wood, flax, jute, sisal, etc.) that are used in fibreboard manufacturing [6]. The most important benefits of selecting the rice straw (which is agricultural residue and grown in large areas of the world) material for medium density fibreboards production are reduction of open field burning of an annual plant and to capture carbon dioxide. In addition, the straw based medium density fibreboards panels can be recycled or converted to energy after utilization.

Bonding agents are those conventionally employed in forming composite products and include both acidic and alkaline type binders. Typical bonding agents are amino resins, phenolic resins, resorcinol resins, tannin resins, isocyanate adhesives or mixtures thereof. Resins which can be used to bond treated straw fibres include urea–formaldehyde resins [1], melamine urea-formaldehyde resins, phenol-formaldehyde [7], resorcinol–formaldehyde, tannin-formaldehyde, polymeric isocyanateb [8] and mixture thereof. The resins can be added in different amounts based on several parameters. Since there are many options to make these plyboards used in primarily household construction, the bending strength comparison is made in the present paper to select appropriate composite for a particular application.

II. EXPERIMENTATION

Sugarcane plywood, particulate plywood composite, pure teak wood and plywood manufactured by different layers of waste wood were taken and the samples for the bend test were cut into appropriate sizes. The experimental test rig can be seen in Figure 1. Since there are fibres in most of these composites and there will be transgranular cleavage fracture in most of these composites, so very slow cross head speeds were selected for the test (0.3 mm per min). Data were recorded for every 2 mm advancement of the bending tool. 3 samples were tested in the similar setup and the average of the data is taken for the analysis. Figure 2 shows the fracture in the material at a certain load and the maximum load at which this fracture appears is noted down. Table-II shows the parameters of various composites used in the experimental. Flexural strength, also known as modulus of rupture, bend strength or fracture strength, a mechanical parameter for brittle material like plywoods, is defined as material's ability to resist deformation under load. The transverse bending test (as discussed in this article) is most frequently employed, in which a rod specimen having either a circular or rectangular cross-section is bent until fracture using a three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture. The modulus of rupture calculated for the various biomaterials by experimentation is also presented in Table II. Figure 3 presents the modulus of rupture calculated under various densities of rice husk composite bonded with urea-formaldehyde resins by El Kassas et al [1].

TABLE II
MODULUS OF RUPTURE OF VARIOUS BIOCOMPOSITES

Material	Dimensions of cross-section (in mm)	Max. load in kN	Modulus of rupture (MPa)
Teak wood	Thickness=21.9 Width = 44.7	2.83	63.36
Sugarcane bagasse Ply	Thickness=18 Width = 65.5	0.83	18.77
Particulate Ply	Thickness=18.7 Width = 65.8	0.32	6.67
Wood Ply	Thickness=18.7 Width = 66.6	1.85	38.12

Fig. 1 Experimental test rig for bend test

Fig. 2 Fractured specimen

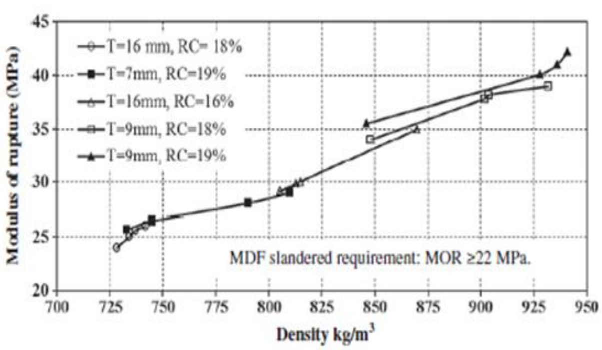

Fig. 3 Modulus of rupture of rice husk plywood at different densities [1]

III. RESULTS AND DISCUSSION

As it can be seen in Figure 3 that the modulus of rupture of for the rice straw biocomposite for medium density board is around 25-40 MPa and it is highly dependent on the density and also the concentration of urea-formaldehyde. From Table-II it can be seen that the modulus of rupture for teak wood is highest i.e. 63.36 MPa and it is known to be the strongest wood but this wood is not only rare but also expensive. Sugarcane bagasse ply is having rupture modulus of 18.7 MPa and this is the cheap material in the regions of the world where sugarcane grows and also these plys are subjected to fungal and other bacterial attacks over a period of time. Particulate material is the wood dust coming out of various process and its rupture strength is very low, (?) but these materials are cheapest. The normal wood ply used in the experimentation was the mixture all the different types of wood waste including teak. That is the reason its strength in quite high, almost similar to the rice straw ply.

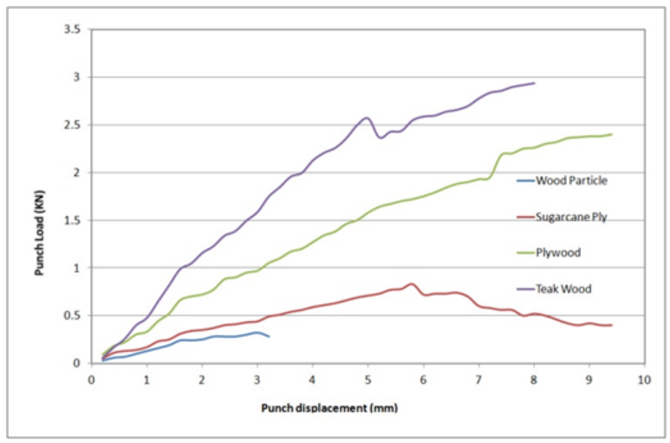

Fig. 4 Comparison of punch load in bend test

Rice straw is dry and tough and it decomposes very slowly in a dry field. Burning old straw is fast and cheap. Unfortunately, the smoke from this practice pollutes the air. This has become a particular nuisance in certain area where rice grows abundantly. This is particularly true in Punjab province of India where rice burning now has been virtually phased out by state regulations. So rice straw biocomposites promises not only strong plywood materials (almost as strong as teakwood) for household constructions but also there is no biological degradation of these materials as in case of sugarcane bagasse. At present only in recent research [1] the main binding agent that is used with the rice husk is urea-formaldehyde. Environmental regulations will continue to challenge the fibreboard industry as urea-formaldehyde resins are dominantly used in the medium density fibreboards industry because of their low cost and fast curing characteristics, they have potential problems with formaldehyde emission. Formaldehyde can cause irritation of the skin, eyes, nose, and throat. High levels of exposure may cause some types of cancers. So some different adhesives preferably some other biomaterial should be used in rice husk to decrease the formaldehyde pollution.

IV. Conclusion

Flexural strength of various biocomposites was compared in this article. Technically teak wood can provide maximum strength fibreboards, but economics of the material may force alternatives. Plywoods manufactured by rice husk promise good and almost comparable strength. Although these plywoods can also be manufactured by some other bio-waste like sugarcane bagasse but there are possible fungal infection in these material over a period of time. But the resins that bonds the rice husk should be replaced with some other bio material as the present bonding material urea-formaldehyde is cancerous.

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